Age-related differences in torque in angle-specific and peak torque hamstring to quadriceps ratios in female soccer players from 11 to 18 years old: A Cross-sectional study

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ABSTRACT

The aim of this study was to evaluate and compare the hamstring (H) and quadriceps (Q) strength, bilateral difference and balance ratios in female soccer players. Ninety-three athletes from three age groups: under 13 (U13), 15 (U15) and 18 (U18) participated in the study performing isokinetic tests to measure peak torque, total work, average power and torque at 30º of thigh muscles. Conventional strength balance ratios, angle-specific balance ratio and bilateral strength difference were evaluated. There was bilateral strength difference for extensor muscles total work ($p = 0.02$) in U13 and flexor muscles peak torque ($p = 0.02$) in U15. All variables were superior in U15 than U13 ($p < .05$). There was no strength difference between U15 and U18. Balance ratios did not differ between sides or age groups. The study showed that although peak torque values were higher in U15 than in U13, balance ratios were similar.

Keywords: athletes[1], exercise[2], women[3]; isokinetic[4], football[5], strength imbalance[6].

INTRODUCTION

The muscular strength profiles of athletes involved with soccer can provide important data about the muscular adaptations due this specific sport demand which occur due to years of sport practice (Voutselas et al., 2007). Furthermore, muscular strength profiles also are useful to better understanding sport performance and for injury risk management (Siqueira et al., 2002).

Previous research has demonstrated that the lower limbs strength and power, mainly for quadriceps and hamstrings muscles, are important factors for basic soccer actions, such as, sprint or fast changes of direction, passing, jumping, kicking the ball or pace quickly (Reilly and Thomas, 1975; Rösch et al., 2000; Stolen et al., 2005). The intense muscular requirement presented in these activities is characterized by an asymmetric kinetic pattern (Hewett et al., 1999; Kotzamanidis et al., 2005), which may cause strength asymmetry (Arnason et al., 2004). Fousekis et al (2010) reported that this strength asymmetry is even more common in athletes with short or intermediate training experience. A deficit range less than 10%, between the lower limbs, has been considered an acceptable value (Daneshjoo et al., 2013). While, strength asymmetric higher than 15% increased the hamstrings injury risk in 2.6 times (Knapik et al., 1991).

Not less important, the strength balance ratio between quadriceps and hamstrings muscles has also been described as an important variable to assess the joint stability. Indeed, these muscles play a crucial role in affecting anterior tibial translation and anterior cruciate ligament (ACL) strain (Hughes and Watkins, 2006). Previous studies showed that the quadriceps increase anterior tibial translation and hence ACL strain, while the hamstrings restraining anterior tibial translation and reducing ACL strain (Myer et al., 2005; Podraza and White, 2010). This factor is especially important for female athletes, who are more prone to present ACL injury (Larruskain et al., 2018).

In this context, higher values for hamstrings and quadriceps strength balance ratio has been suggested to be associated with better performance (Trzaskoma et al., 1995) and with a lower risk injury, such as ACL rupture (Cheung et al., 2012). Traditionally, the strength balance ratios for the knee joint has been measured with peak torque values for hamstrings and quadriceps muscles, which represents a single maximum torque values observed in the torque–angle curve at a predetermined velocity. This ratio has been assessed between concentric hamstrings peak torque to concentric quadriceps peak torque (Dvir et al., 1989), and it has been called as conventional strength balance ratio. Previous studies suggest that this ratio should be 0.6 (Hewett et al., 1999, 2008; Jenkins et al., 2013). On the other hand, actual literature remains controversial about the predictive role of these peak torque strength ratios to predict ligament injuries (Bennell et al., 1998; Kannus and Järvinen, 1990; Kim and Hong, 2011; Myer et al., 2009; Sharir et al., 2016), and this controversy may be attributed to the way how the strength balance ratio has been measured. The ratio between antagonist muscles peak torque has been criticized because the muscles peak torque does not occur at the same angle of the range of motion (Eustace et al., 2017). Peak torque of extensor muscles has been reported ~70ºof range of motion (from full extension), and peak torque of flexor muscles has been reported ~30º (Andrade et al., 2012; Coombs and Garbutt, 2002; Eustace et al., 2017). As consequence, besides hamstrings to quadriceps peak torque ratios, other strength balance index has been advocated, as antagonists' muscles torque ratio of the same angle specific torque (Eustace et al., 2017). Hamstring to quadriceps torque ratio, near to full extension, such as at 30º has been suggested as a better way to evaluate the knee stability and the knee injury risk factor, considering the high knee injuries at extended knee joint angles (Boden et al., 2000; Eustace et al., 2017; Hewett and Myer, 2011; Higashihara et al., 2015; Olsen et al., 2004).

While, bilateral strength deficit and angle-specific measures of isokinetic strength have been assessed in male soccer players presenting different years of practicing (Cohen et al., 2015; El-Ashker et al., 2017; Evangelidis et al., 2015), there are few data for female soccer players athletes. The knowledge of the female strength profile is very important once the number of female soccer player are increasing and female athletes presented higher knee injuries, such as ACL injury, than the male athletes (Hägglund and Waldén, 2016; Larruskain et al., 2018). Moreover, previous data suggested that there are a significant difference in hamstrings to quadriceps torque ratio between sexes (Andrade et al., 2012; Hewett et al., 2008; Hughes and Watkins, 2006); therefore, the existing that available for male athletes cannot be used for female athletes .

Thus, the aim of the present study was to evaluate and compare peak torque values, bilateral strength deficit, hamstrings to quadriceps peak torque ratio and hamstrings to quadriceps angle-specific ratio in female soccer players from 11 to 18 years old. We hypothesized that the older female soccer players will present higher strength values for flexor and extensor muscles than the younger, but the balance ratios will not change with the training years. Muscle asymmetries will be expected in the younger group, because they have a short training experience.

METHODS

Participants

Ninety-three female soccer players voluntarily participated in this study and were divided into groups from three age groups: Under 13 (U13), U15 and U18. The participants were recruited from the female soccer team of the Olympic Training and Research Center (São Paulo, Brazil) and had participated in events at national level, between 2016 and 2018. The athletes were invited through contact with the coach. Athletes were required to be engaged in a soccer training routine with a frequency of three to four times a week, two or three hours per day, for at least two years. And also, strength training two times a week, one hour per day.

Athletes who suffered a lower limb injury in the last six months were excluded from the study. On the day of the isokinetic muscle evaluation, the participants were free of pain or discomfort. The physical characteristics (i.e. age, weight, height and BMI) of the participants are summarized in Table 1

After receiving instructions regarding the experimental procedures, their possible risks and benefits, as well as the objectives and justification of the research, the parents or guardians (for those athletes under 18 years old) and athletes signed the consent form. All the experimental procedures of the study were approved by a proper research ethics committee (approval number: 80282817.0.0000.5505) and meets the ethical standards of the Declaration of Helsinki.

Table 1 about here

Experimental procedures

Before the experimental procedures were undertaken, each athlete visited our laboratory to receive instructions about the study and to answer a questionnaire about the physical training habits and injury history. If the athlete attends the inclusion criteria and the parents or guardians (for those athletes under

18 years old) and athletes signed the consent form of the study. Athletes weight was measured using a portable scale previously calibrated to the proximal 0.1kg, and height has measured using a stadiometer calibrated to 0.1cm (Filizola, São Paulo, Brasil). After that, isokinetic muscle strength evaluation was performed.

The isokinetic muscle evaluation was performed using the isokinetic dynamometer, Biodex System 3 (Biodex Medical System, Shirley, NY, USA). Prior to the test, participants performed five-minute warm up by going up and down a ladder, and a light dynamic muscle stretching of lower limb muscles. This kind of stretching generates minimum impairment to muscle strength (Mascarin et al., 2015). The adopted position was seated (approximately 90º hip flexion) with trunk, hip and thigh fixed with bands to minimize body movements and isolate knee joint movements. The distal fixation was placed two centimeters above the lateral malleolus of the fibula. The axis of the isokinetic dynamometer was aligned with the lateral epicondyle of the femur. The limit of the range of motion was determined by goniometry. Full extension was considered as 0º. Movement started at 90º of knee flexion to full extension. Gravity correction was done for each lower limb before the test to reduce the risks of imprecision.

The test started with the dominant lower limb, determined by asking the participants which limb they preferred to use when kicking a ball. Both lower limbs were evaluated. All volunteers were instructed verbally about the procedure and received standardized incentives during the test. The test consisted of five maximal concentric repetitions of knee flexion and extension at angular speeds of $60º.s^{-1}$ and $240º.s^{-1}$. Among the angular speed tested there was an interval of sixty seconds and between the limbs tested there was an interval of three minutes. For familiarization, the participants were given standard verbal instructions regarding the procedures and allowed several submaximal practice attempts (de

Lira et al., 2017). The following variables were measured: peak torque (Nm) at 60º.s^{-1} and 240º.s^{-1}, total work (J) at 60º.s^{-1} and 240º.s^{-1}, torque at 30º (torque measured at 30 degrees of range of motion) (Nm) at 60º.s^{-1}, and average power (W) at 240º.s^{-1} of the knee flexor and extensor muscles. The conventional strength balance ratios (peak torque of the flexor muscles / peak torque of the extensor muscles) and the angle-specific balance ratio (torque at 30º of the flexor muscles / torque at 30º of the extensor muscles). Limb symmetry indexes (LSI) were calculated by the following equation.

$$\boldsymbol{LSI = \left[\frac{(dominant\ limb\ data - non\ dominant\ limb\ data)}{dominant\ limb\ data}\right] X\ 100}$$

Statistical analyses

Statistical analyses were performed using the Statistica software (Statsoft, Inc., version 6.0 for Windows, USA). Data were expressed as mean ± standard deviation (SD). Variable distribution was tested by the Kolmogorov–Smirnov test, and variability by the Levene test. Two-way ANOVA was used to assess group (U13 vs. U15 vs. U18) and side (dominant vs. non-dominant) differences in the isokinetic parameters. When significant group-by-side interactions were present, Tukey's post-hoc procedures were used to identify the specific differences. In the absence of interactions, only the main effects were analyzed. In order to compare conventional strength balance ratio with recommended literature value of 60%, a single sample t-test was conducted. Statistical significance was set at an alpha of .05.

RESULTS

There were seventy five percent of right-handed athletes in U13, eighty three percent in U15 and seventy two percent in U18. Athletes in U15 presented significantly higher values for age, weight, height and BMI than U13 (Table 1). However, only age was different between U15 and U18 (Table 1).

In the comparison of the results obtained in the isokinetic muscle evaluation of the dominant and non-dominant limbs, it was observed that U13 athletes had significantly higher total work of the extensor muscles (240º.s^{-1}) (P = .02, 8%) of the dominant side and U15 athletes presented significantly higher peak torque of the flexor muscles (240º.s^{-1}) (P = .02, 6%) of the dominant side when compared with non-dominant side. U18 athletes had no significant contralateral difference (Table 2).

When comparing the age groups U13, U15 and U18, a significant increase (p> .05) from age group U13 to U15 was observed in all measured parameters of knee extensor muscles, for both lower limbs. Age groups U15 to U18 did not significantly differ (Table 2). It is also observed that the torque values measured at 30º are significantly lower than the peak torque values (p <.05) when comparing the extensor muscles of the same limb and of the same age group. The percentage values of this difference were between 65 and 52%.

<u>Table 2 about here</u>

Comparing the knee flexor muscles, the U15 athletes presented a significant difference of the peak torque values at 240 deg·s^{-1} between dominant and non-dominant limbs [1] (P = .02, 6%). The U13 and U18 athletes showed no significant contralateral differences (Table 3).

When comparing the different age groups, it was also possible to observe a significant increase (p <.05) from age group U13 to U15 in all parameters measured from the knee flexor muscles, both dominant and non-dominant. Among U15 and U18 athletes there was no significant difference in the parameters evaluated for the knee flexor muscles (Table 3). It is also observed that the torque values measured at 30º are significantly lower than the peak torque values ($p < .05$) when comparing the flexor muscles of the same limb and the same age group. The percentage values of this difference were between 16 and 33%.

Table 3 about here

The conventional strength balance ratios (peak torque of the flexor muscles / peak torque of the extensor muscles) and the angle-specific balance ratio (torque at 30º of the flexor muscles / torque at 30º of the extensor muscles) of U13, U15 and U18 did not present significant contralateral differences nor significant differences among age groups. The three age groups presented significantly lower values of conventional muscle balance ($p < .05$) than the reference value determined in the literature (60%) (Table 4).

Table 4 about here

DISCUSSION

The aim of the present study was to evaluate and compare between different female soccer players age groups the knee muscular strength, side-to-side strength differences, and the strength balance ratios. We also aimed to compare peak torque values with torque values assessed at 30º. The main results of the study were, that despite the peak torque values being higher in U15 age group than in U13, the knee balance ratios maintained stable between age groups assessed. Another interesting data is that the conventional balance ratio was lower than the literature recommendation (60%) for all the age groups, and there were no important muscular asymmetries in any age group.

The parameters of peak torque (the highest torque value developed during the range of motion), total work (the integral of the torque–angle curve) and average power (the time expended to perform the total work) are often used to evaluate the isokinetic muscular performance of a given population (Dvir, 2014). In the present study, we observed that the U15 athletes presented values of torque, work and power of the flexor and extensor muscles significantly higher than the U13 age group; while there were no significant differences between the U18 and U15 athletes. These results were expected since muscle adaptations are more evident in younger athletes and in the early years of training, and then become less evident (Fousekis et al., 2010). Moreover, the athletes were also growing up between U13 and U15 (U15 presented higher values for height and body mass than U13), which also contribute to the higher strength values observed in U15. Our data was according to previous data reported for male soccer players. Kellis et al. (2000) demonstrated that body mass and age were strongly associated with concentric isokinetic thigh muscles strength, and they are the main predictor variables for concentric isokinetic strength. Between U15 and U18, there were no significant difference in weight and height values, then this may be the reason for the lack of isokinetic muscular strength difference. BMI was higher in U15 than in U13 athletes. Previous literature data have demonstrated that higher BMI were associated with lower muscular strength (Bonney et al., 2018). This apparent contradictory data can be explained because previous study compared people with normal BMI with overweight people, which is different in our study. Athletes in U15 were classified as normal weight and the athletes in U13 were classified as underweight, which may be harmful for strength development.

Regarding the asymmetry of muscular strength, we observed that the U18 athletes did not show any asymmetry, age group U15 presented asymmetry of flexors peak torque at $240^{o}.s^{-1}$ and, age group U13, of extensors total work at $240^{o}.s^{-1}$. In fact, we can expect more evident asymmetries of strength in younger athletes than the more experienced ones, since the younger ones do not present sufficient maturity of the kinetic and neuromuscular patterns to deal with the asymmetry present in the sport (Fousekis et al., 2010). On the other hand, although these contralateral differences have been identified, it is worth noting that in percentage values, these differences are less than 10%, which is within a limit of normality determined in the literature (Daneshjoo et al., 2013). Thus, although there were significant contralateral differences, we can consider that they are not important from the clinical point of view. Another interesting point to note is that despite soccer is an asymmetrical sport, the whole group evaluated did not present significant muscular asymmetry, contrary to the initial hypothesis of the study.

The conventional muscle balance ratios were not different between the age groups, indicating that there is a strengthening of the same magnitude of both muscle groups over the years of sports practice. Moreover, conventional muscle balance ratios presented by the dominant and non-dominant limbs of all age groups were lower than 60%, which is the lower limit recommended by the literature (Hewett et al., 1999, 2008; Jenkins et al., 2013). Andrade et al. (2012) studied men and women soccer players. The authors also found low ratios for women (54 ± 11%), but not for men (66 ± 12%). Values below this recommendation in the literature were also found by (Vargas et al., 2019) for women soccer players and by Lira et al. (2017) for male soccer, futsal and beach soccer players. It is possible that the lower conventional ratio presented by soccer player athletes was associated with ACL injury, which is one of the most frequent severe knee injuries in this population (Chomiak et al., 2000). However, prospective studies should be performed to elucidate this question.

In addition to the conventional balance ratio, angle-specific balance ratio at 30º also was studied. The assessment of muscle balance at the 30° angle is suggested because the greatest occurrence of knee injuries, such as ACL injury, or hamstrings injuries, occurs at the end of the range of motion (Baldon et al., 2011; Eustace et al., 2017).

In the same way as the conventional balance ratio, the angle-specific balance ratio was also not different between the age groups nor between dominant and non-dominant limbs of the same age group. The values of angle-specific balance ratio were significantly higher than those observed for the conventional ratio. The torque curve of the extensor muscles has a rather different morphology than the hamstrings muscles torque curve (El-Ashker et al., 2017). In the present study, it is observed that the torque value of knee extensor muscles assessed at 30º is much lower than the peak torque value of the same muscles (52% to 65%, depending on the age group). On the other hand, the torque value of knee flexor muscles assessed at 30º is not so different from the peak torque values of the same muscles (16 to 33% depending on the age group). As in the 30º evaluation, the strength of extensors muscles decreases much more in relation to the flexor’s strength, the ratio between both becomes higher and, in most cases, exceeds 100%. Numerous studies have shown that the knee extensor muscles action increase anterior tibial translation (particularly with the knee close to full extension) and hence ACL strain, on the other hand, the knee flexor muscles are responsible to restrain anterior tibial translation and reduce ACL strain. Therefore, it is possible that a higher strength balance ratio at 30º (higher than 100%) should be important to stabilize the knee joint avoiding ACL strain. However, prospective studies also should be done in order to establish the role of angle-specific balance ratios.

One potential limitation of the study is the lack of eccentric torque evaluation, which makes it impossible to study functional strength balance ratio, the ratio between eccentric action of flexor muscles and concentric action of extensor muscles. The possibility to evaluate the functional ratio would contribute to a better understanding of the knee joint dynamic instability. Thus, further studies with knee muscles eccentric evaluation are needed.

Conclusion

The present study demonstrated that young female soccer players from 11 to 18 years old, despite of the asymmetric characteristic of the sports activities, the dominant and non-dominant limbs demonstrated symmetrical strength in the knee joint muscles. Knee conventional balance ratio also demonstrated no differences between dominant and non-dominant limbs and age groups. On the other hand, all age groups presented conventional balance ratio lower than the literature recommendation, evidencing a flexor muscles insufficiency. The strength balance ratio at 30º also presented no difference between dominant and non-dominant limbs and age groups. This data from female soccer players can be compared to other athletes to help determine individual weaknesses, strengths, and imbalances, and may be useful for designing training or rehabilitation programs. Finally, these results can be used as normative data regarding isokinetic profiles in female young soccer players athletes.

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Author Contributions Statement

MA and MJ conceived the original idea and planned the experiments. All authors provided critical feedback and helped shape the research, analysis and manuscript. MJ carried out the experiment with support from AS. MA, CL, RLV, TR, PTN and BK planned and carried out the statistical analyses. All authors discussed the results and contributed to the final manuscript. MA took the lead in writing the manuscript with support from CL, RLV, TR, PTN and BK.

Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Data Availability Statement

The anonymized data used to support the findings of this study are available from the corresponding author upon request.

Funding

No funding to declare.

Contribution to the Field Statement

The muscular strength profiles of athletes involved with different sports modalities can provide a basis for understanding muscular adaptations due to specific training, the requirements necessary for sport success, and injury risk management. Once a high muscular demand of hamstring and quadriceps muscle are present in soccer players, several previous studies have studied isokinetic strength profile for male athletes providing valuable information for them, but less is known for female soccer players. Therefore, it is unclear how soccer affects side-to-side difference and strength balance ratios in female adolescents' athletes. Characterization of these isokinetic knee parameters may contribute to a better understanding of muscular adaptation generated in female soccer players, moreover, reference values can be helpful to direct strength training and rehabilitation processes.

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Table 1. Physical characteristics of athletes of age groups U13, U15 and U18.

	U13 n=35	U15 n=36	U18 n=22
Age (years)	11.83 ± 0,.7 (11.00-13.00)	13.72 ± 0.51* (13.00-15.00)	16.10 ± 0.89# (15.00-18.00)
Body mass (kg)	40.75 ± 7.54 (29.00 - 65.00)	53.95 ± 7.42* (40.00 – 70.90)	55.66 ± 8.96 (36.90 - 69.00)
Height (m)	1.51±0.06 (1.36-1.67)	1.60±0.05* (1.49-1.77)	1.60±0.07 (1.47-1.71)
BMI (kg/m²)	17.7±2.6 (14.3-27.3)	20.7±2.3* (16.3-25.5)	21.7±3.4 (15.5-29.1)

Mean±SD (min – max).

SD (standard deviation), min (minimum), max (maximum)

*P<.05 (U15 ≠ U13)

#P<.05 (U18≠ U15)

Table 2. Isokinetic muscle evaluation of dominant and non-dominant knee extensor muscles, age groups U13, U15 and U18.

	U13 n=35		**U15 n=36**		**U18 n=22**	
	Dominant	**Non-dominant**	**Dominant**	**Non-dominant**	**Dominant**	**Non-dominant**
PT 60^{o}.s^{-1} (N-M)	91.1 ± 19.4 (57.1 - 124.7)	88.5 ± 20.3 (52.2 - 133.5)	137.6 ± 21.7# (99.7 - 175.0)	135.9 ± 30.0# (58.2 - 187.7)	146.5 ± 28.3 (77.3 – 184.0)	145.2 ± 32.0 (79.0 – 211.8)
TW 60 ^{o}.s^{-1} (J)	92.9 ± 20.8 (57.1 - 149.3)	90.4 ± 21.7 (52.2 – 133.5)	159.4 ± 31.3# (98.8 - 216.1)	154.2 ± 33.2# (90.7 - 224.1)	170.0 ± 40.0 (93.5- 250.9)	173.3 ± 40.4 (102.3 - 243.2)
PT 240 ^{o}.s^{-1} (N-M)	58.2 ± 18.2 (32.9 – 138.6)	59.6 ± 22.0 (32.8 - 167.1)	82.0 ± 13.0# (54.0 - 104.4)	79.7 ± 15.2# (36.8- 108.1)	88.3 ± 17.2 (57.3 - 116.8)	88.1 ± 16.9 (59.9 - 112.0)
TW 240 ^{o}.s^{-1} (J)	69.9 ± 16.6 (38.8 – 113.6)	76.1 ± 19.5* (28.1 - 112.8)	107.0 ± 38.7# (105.3 - 245.1)	106.3 ± 18.6# (68.7 - 138.5)	118.8 ± 26.5 (67.8 - 159.9)	117.5 ± 25.1 (72.5 - 158.4)
AVG P 240 ^{o}.s^{-1} (Watts)	114.6 ± 31.5 (50.4 - 13.5)	123.4 ± 32.0 (66.6 - 199.6)	181.3 ± 36.0# (245.1 – 105.3)	181.2 ± 36.2# (96.2 – 244.0)	205.6 ± 48.0 (117.8 – 282.0)	204.7 ± 41.9 (113.2 - 257.7)
T30^{o} 60 ^{o}.s^{-1} (N-M)	37.4 ± 15.8& (13.2 - 93.7)	31.8 ± 11.8& (11.8 - 56.4)	60.4 ± 15.9#& (28.9 - 85.1)	56.7 ± 19.5#& (26.3 - 94.5)	71.4 ± 21.0& (31.3 - 96.7)	67.2 ± 25.5& (23.7 - 115.8)

*P<.05 (dominant ≠non-dominant).

#P<.05 (U15≠U13 - same member)

&P<.05 (T30^{o} ≠ PT60^{o}.s^{-1})

Mean±SD (min – max).

SD (standard deviation), min (minimum), max (maximum), PT (peak torque), TW (total work), AVG P (average power), T30º (torque rated 30º)

Table 3. Isokinetic muscle evaluation of dominant and non-dominant knee flexor muscles of age groups U13, U15 and U18.

	U13 n=35		**U15** **n=36**		**U18** **n=22**	
	Dominant	**Non-dominant**	**Dominant**	**Non-dominant**	**Dominant**	**Non-dominant**
PT 60°/s (N-M)	49.4 ± 12.6 (27.3 - 76.6)	47.7 ± 12.1 (26.6 - 71.1)	77.4 ± 13.4# (50.2 - 103.5)	73.9 ± 13.3# (53.0 - 105.5)	81.8 ± 16.1 (47.4 - 105.5)	78.8 ± 16.5 (40.4 - 109.8)
TW 60°/s (J)	59.7 ± 18.7 (28.3 - 101.4)	59.5 ± 16.3 (31.2 - 95.2)	97.8 ± 19.8# (60.3 - 130.5)	95.3 ± 21.0# (58.4 - 152.2)	105.8 ± 24.5 (59.0 - 151.1)	99.2 ± 23.5 (50.6 - 135.3)
PT 240°/s (N-M)	38.3 ± 8.1 (22.0 - 55.3)	36.2 ± 9.6 (16.1 - 59.3)	55.0 ± 10.1# (38.1 - 79.2)	52.0 ± 9.0*# (37.8 - 75.7)	59.0 ± 11.0 (35.6 - 74.9)	55.8 ± 10.6 (37.2 - 71.8)
TW 240°/s (J)	43.2 ± 13.3 (10.1 - 76.1)	43.8 ± 13.0 (22.7 - 69.6)	68.1 ± 16.4# (33.3 - 105.6)	66.1 ± 12.4# (36.7 - 87.2)	75.0 ± 14.2 (43.8 - 99.4)	71.5 ± 13.5 (48.2 - 88.7)
AVG P 240°/s (Watts)	46.1 ± 16.7 (10.1 - 101.3)	45.8 ± 16.2 (19.7 - 99.7)	112.7 ± 30.5# (47.2 - 179.0)	108.7 ± 24.1# (56.9 - 152.7)	123.5 ± 24.7 (65.1 - 163.0)	118.8 ± 25.3 (70.2 - 147.9)
T30º 60°/s (N-M)	34.1 ± 13.8& (13.2 - 74.0)	32.1 ± 10.7& (7.6 - 52.4)	59.9 ± 16.3#& (34.8 - 90.0)	55.6 ± 19.7#& (11.4 - 92.1)	68.8 ± 17.9& (26.3 - 99.3)	62.7 ± 21.8& (22.2 - 88.4)

*P<.05 (dominant ≠non-dominant).

#P<.05 (U15≠U13 - same limb)

&P<.05 (T30º ≠ PT60°/s)

Mean±SD (min – max).

SD (standard deviation), min (minimum), max (maximum), PT (peak torque), TW (total work), AVG P (average power), T30º (torque rated 30º)

Table 4. Conventional strength balance ratios (FLEX/EXT) and the angle-specific balance ratio (FLEX 30º/EXT 30º) of age groups U13, U15 and U18.

	U13		**U15**		**U18**	
	Dominant	**Non-dominant**	**Dominant**	**Non-dominant**	**Dominant**	**Non-dominant**
FLEX/EXT 60°/s (%)	54.29 ± 7.68┼ (36.50 - 69.56)	53.94 ± 6.56┼ (45.17 - 69.39)	56.38 ± 5.59┼ (37.08 - 66.94)	55.75 ± 9.48┼ (44.70 - 93.13)	56.26 ± 6.60┼ (43.81 - 68.39)	54.67 ± 5.77┼ (45.69 - 65.81)
FLEX 30º/EXT 30º 60°/s (%)	110.80 ± 73.82 (37.39 - 341.67)	114.67 ± 55.84 (37.44 - 261.49)	105.03 ± 38.63 (54.40 - 238.23)	103.36 ± 36.27 (24.67 - 193.18)	99.88 ± 22.90 (59.74 - 145.57)	99.16 ± 36.12 (42.61 - 195.02)

*P<.05 (dominant ≠ non-dominant).

┼P<.05 (lower than the reference values – 60%).

Mean±SD (min – max).

SD (standard deviation), min (minimum), max (maximum), FLEX (flexors), EXT (extensors), DM (dominant), NDM (non-dominant).